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Foraminiferal Biostratigraphy and Paleoenvironmental Study of 'MR'- Well, Southeastern Niger Delta, Nigeria

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Abstract

A high resolution biostratigraphic technique, using ditch cutting samples and well log datasets was employed in 'MR'-well in the Coastal Swamp Depobelt of the Niger Delta. The aim of this study is to evaluate foraminiferal biostratigraphy and paleoenvironment of the analyzed well. The interpretation of the well section sediments showed that the analyzed litho-units is dominated by alternating shale and sand succession, with silt intercalations, which belongs to the Agbada Formation of the Niger Delta. Biostratigraphic analysis revealed the penetration of three foraminiferal zones: *Catapsydrax stainforthi* (N6)*, Globigerina tellainsueta /Praeorbulina glomerosa* (N7-N8) and *Globorotalia foshi peripheroronda /Globorotalia foshi foshi /Globorotalia foshi lobata /Globorotalia foshi robusta* (?N9-N10 and younger). These delineated zones fall between Early Miocene - 'earliest' Middle Miocene age. The results suggest that the sediments were deposited in Shallow-Inner Neritic to Upper bathyal paleoenvironmental setting**.**

Keywords: Foraminiferal zones, Environments of deposition, Coastal Swamp Depobelt and Niger Delta.

Introduction

The Niger Delta is located in the Gulf of Guinea, Southern Nigeria and has become the most studied delta in the Southern Sahara due to its hydrocarbon potentials. Several oil wells have been drilled by various producing oil companies to derived information about this basin, such information includes hydrocarbon potentials, sedimentology, paleoecology, biostratigraphy, lithostratigraphy, among others. In order to contribute to the wealth of knowledge of the basin, this work used ditch cutting samples and wireline log signatures from 'MR'- well within the depth interval of 4370 - 3370m (Fig. 1). This study utilizes foraminiferal biostratigraphic concepts coupled with some indicial taxa for its zonation, dating and inferring the depositional setting penetrated by sediments of this well. This study will also foster and also contribute to the understanding of the petroleum exploration and exploitation of this basin.

Geologic Setting and General Geology of the Niger Delta

The Niger delta is located on the continental margin of the Gulf of Guinea in Equatorial West Africa. It is located at the southern margin of Nigeria between latitude 3^{o} and 6^{o}N and longitude 5^{o}E and 8^{o}E.

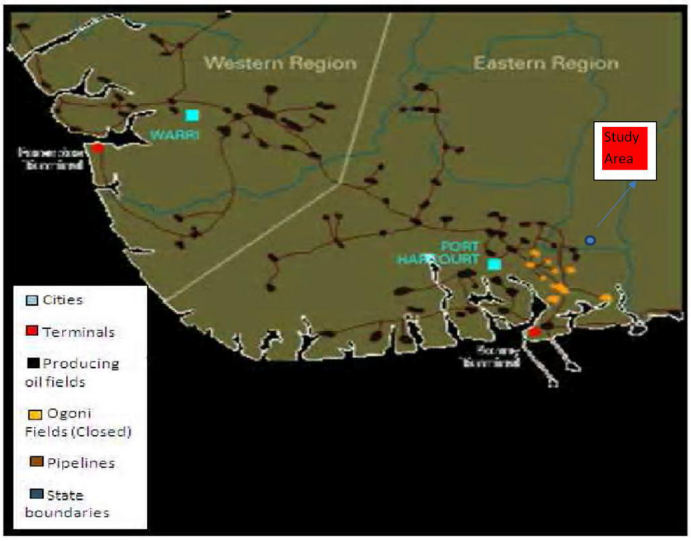

Fig.1. Location map of the Niger Delta showing 'MR'-Well (Modified from Imasuen et al., 2011).

The Niger Delta province is delineated by the geology of southern Cameroun stable megatectonic frames and West African shield, these include; Benin and Calabar hinge lines at the northwestern and eastern boundaries of the delta respectively. However, the Gulf of Guinea borders the Niger delta basin in the south and the base of the Benue Trough, Anambra Basin and Abakaliki High complete the northern boundary (Fig. 2). This configuration of the basin reflects the overall regression of depositional environment within the Niger delta clastic wedge (Oyedele et al., 2012 and 2013).

Three main lithostratigraphic units have been recognized and delineated in the Niger Delta (Short and Stauble, 1967) and these are: Akata, Agbada and Benin Formations, respectively (Fig. 3). These reflect a complex mixture of marine, fluvio-marine, littoral and deltaic plain environments (Weber and Daukoru, 1975). The Akata Formation is the basal sequence and is characterized by uniform shale and silt development. The formation is predominated by shale which is generally dark grey with little plant remains and mica. The marine planktonic foraminifera is about 50% of the microfauna assemblage found within this setting and grossly suggesting shallow marine shelf deposition. The age of this section spans from Paleocene- Recent (Doust and Omatsola, 1990) and the shale is about 600m thick which is a major source of hydrocarbon generation within the delta. Overlying the basal marine unit is the paralic Agbada Formation which is made up of alternating sandstone, siltstone and shale deposits. The percentage of sand sediments increased upward while that of shale decreases. This indicates a cyclic sequence of fluvial and marine deposits. This formation extends throughout the Niger delta subsurface and is the most explored unit. The age of Agbada Formation decrease from north to south spanning Eocene to possibly Pleistocene (Short and Stauble, 1967). The formation is about 4500m thick and contains hydrocarbon prospective sequences within the Niger delta. The Benin Formation is the topmost section and remains the shallowest part of the deltaic clastic wedge. According to Ojo and Gbadamosi (2013), this formation can be easily recognized based on its high percentage sand occurrence (9:1) which reflects high resistivity log signatures. The Benin Formation has a few shale intercalations (Bustin, 1988) and recorded a huge continental deposits thickness of about 200m (Beka and Oti, 1995) with an age range of Oligocene in the north and becomes progressively younger southward.

From the inception of the Niger delta to the present the delta has been prograding into the adjoining Oceanic crust southward, forming the most active portion of the delta at each stage of its development called the depobelt (Doust and Omatsola, 1990). The Niger delta has major faults, which are syn-

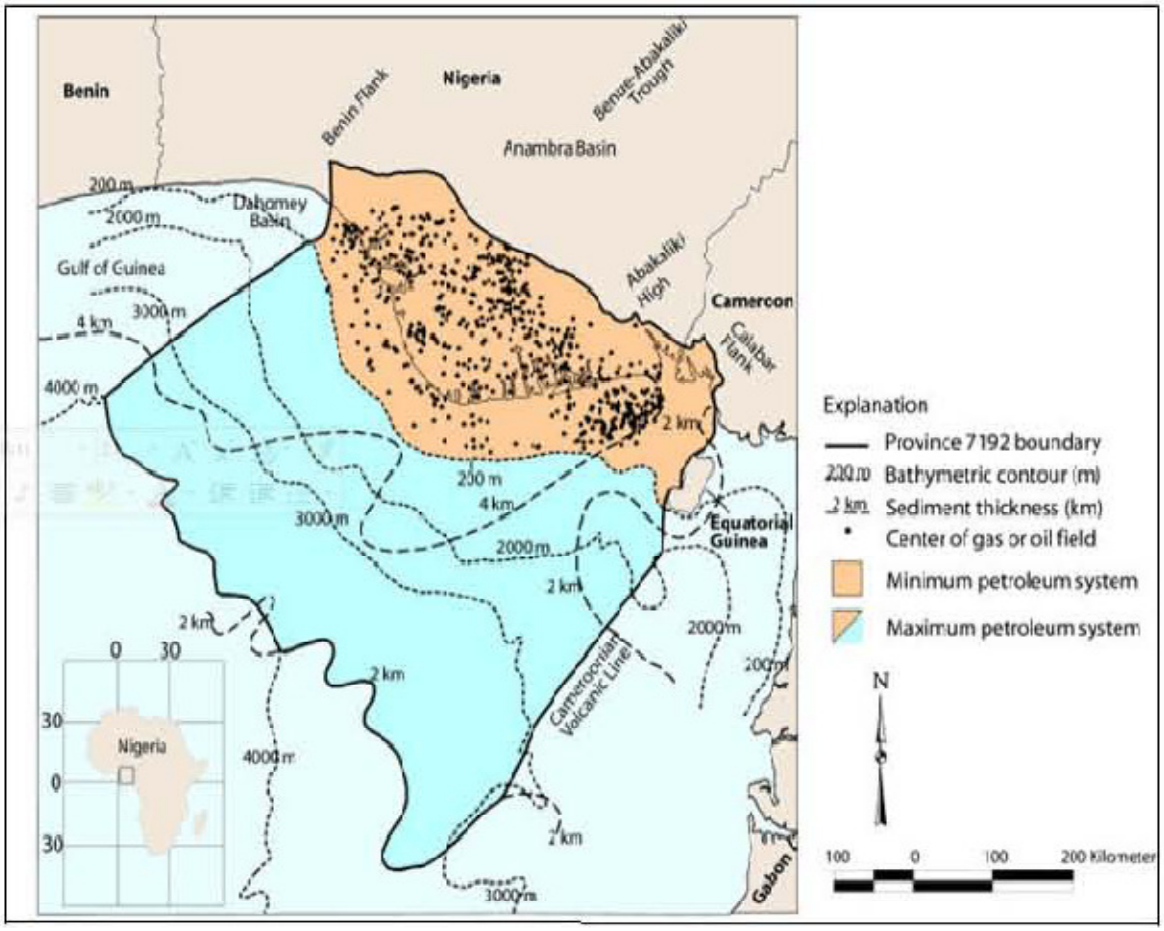

Fig.2. Map of the Niger Delta showing provincial outline with maximum petroleum systems (Modified from Tuttle et al., 1999).

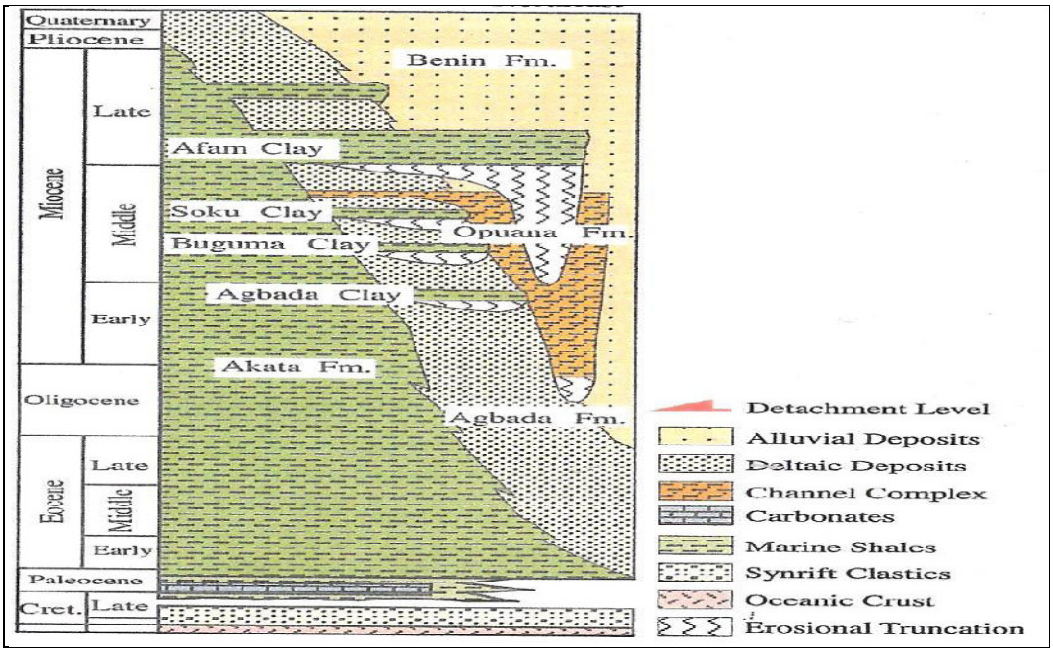

Fig. 3. Stratigraphy of the Niger Delta showing the various Formations (Modified after Adeigbe et al., 2012).

sedimentary structures called the growth faults, which are the major building faults in the delta and is restricted to the paralic Agbada Formation and some bound the depobelts.

The Niger delta province has been identified to contain one well known petroleum system known as the Tertiary Niger delta (Akata- Agbada) Petroleum System (Ekweozor and Daukoru, 1984 and Kulke, 1995). Hydrocarbon is produced from rocks (sandstone and unconsolidated sands) of Eocene to Pliocene age in the onshore areas and from Pliocene to Pleistocene age in the offshore sections, with expected production from the flanks of Cretaceous rocks (Ozumba, 1999). The hydrocarbon production is controlled by the dominant growth fault system found within the setting.

Materials and Methods

A total of one hundred (100) ditch cutting samples of belonging to 'MR'- well within the interval depth of 3370 - 4370m were collected at ten meters (10m) interval for analysis of foraminiferal micropaleontology and lithologic samples preparation. Wireline logs were also obtained.

The conventional approach for the processing of samples for foraminiferal biostratigraphy was employed. The ditch cutting samples were packed in envelopes with codes showing retrieved depths and were later rinsed to remove drilling mud and then dried. A standard weight (20 grams) of each dried sample was soaked with one teaspoonful of anhydrous sodium carbonate in water for thorough disintegration overnight. The disaggregated samples were then washed through tap water over a 63-micrometer (μm) mesh-sieve. The washed residue were then dried over a hotplate at a minimum temperature of 20^0C and then sieved into coarse, medium and fine fractions respectively. The dried residues were then stored into well labeled sample bag. Picking was done with the aid of a picking tray and a stable hair paint brush (N00) under binocular microscope. Identification of the foraminiferal taxa was made possible with the taxonomic schemes of Leoblich and Tappan (1964) and other relevant recent publications found useful within in the Niger delta region.

Results and Interpretation

Lithofacies Analysis

The interpretation of the litho-units within the well followed a careful understanding of the gamma log motifs, since this shows changes within the constituent sediments being deposited. However, the lithology encountered within this well section is dominated by alternating shale and sand with intercalated sandstone/sits. The shale/sand ratio is approximately 7:3; with coarsening and fining upward sequences trend. The shale sediments encountered within this well is characterized by light grey to brownish, sub-fissile to fissile, moderately hard with shell fragments, gypsum and micromicaceous materials depicting accessories. The sand/ sandstone is characterized by fine to medium and sometimes coarse grained, clean - colourless, moderate to well sorted, subangular – subrounded grains. Ferruginous and calcareous materials also occurred.

Foraminiferal Biostratigraphy

A total of one hundred and twelve (112) foraminifera species were identified from the 'MR'-Well in the study area. Out of this number, ninety-six (96) were benthics (calcareous and arenaceous) representing about 79% of the total number of foraminifera species, while planktic foraminifera were twenty-three (23 species) constituting about 21%. The benthic categories has calcareous taxa (73 species) amounting to 65% and predominated over the agglutinating taxa (16 species) which constituted about 14% of the benthic taxa analyzed from the well. The results of the

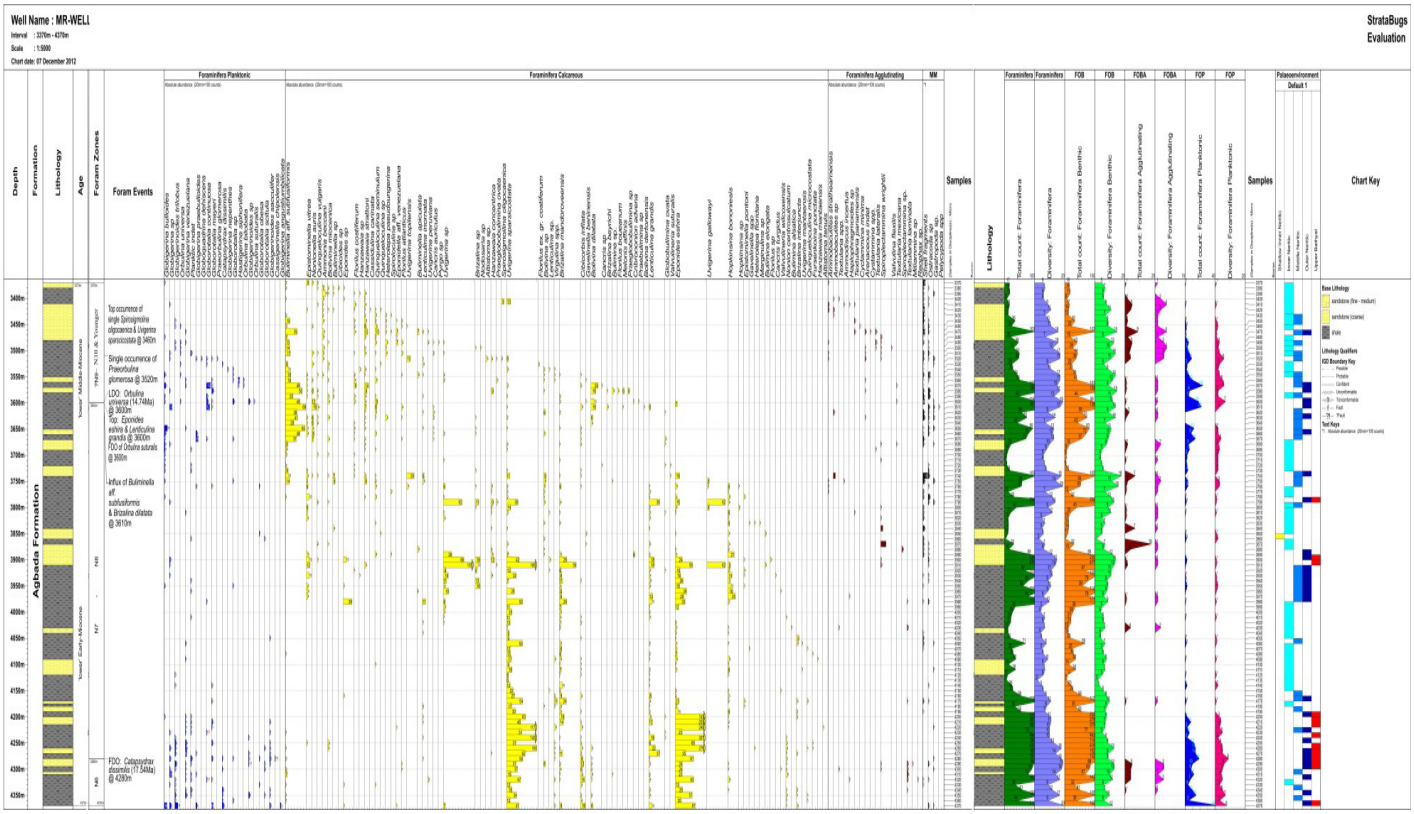

Fig.4. Foraminifera Biostratigraphic Chart of MR Well.

analyzed MR Well is shown in Fig. 4 and few photos of foraminifera are shown in Plate 1 and Plate 2.

The foraminifera biozonation erected in this work is based on occurrences of some key marker species. However, the benthic zonation adopted in this study make used of some Niger Delta marker species that have chronostratigraphic value (Fajemila, 2012). The zonal boundary were delineated based on the observed candidate surfaces [Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB)] and the result correlated to the zonal classification by Blow (1969), Bolli and Saunders (1985), Berggren et al., (1985) and Hardenbol et al., (1998).

From the result of the analysis of 'MR'- well the following foraminiferal zones were identified:

1. *Catapsydrax dissimillis/ Bulliminella subfusiformis* Zone (4370 - 4230m)

This is the oldest foraminiferal zone identified in the investigated area. The base of this zone is witness at the total depth of the analyzed well at 4370m and the top is defined by the oldest encountered Maximum Flooding Surface (17.4/Bur.4Ma MFS) at 4230m. It has been observed that one of the zonal markers within this zone is the Last Downhole Occurrence (LDO) of *Bulliminella subfusiformis* at 4340m.The top of this zone is marked by the First Downhole Occurrence (FDO) of *Catapsydrax dissimillis* as a designated zonal marker at 4280m.Foraminifera occurrence is moderately to fair in abundance and diversity. Calcareous benthic foraminifera assemblage characterizing this zone include *Hopkinsina bononiensis*, *Uverigina sparsicostata (*Cushman & Laiming) *Cibicorbis inflata*, *Gaveniella beninensis*, *Lenticulina grandis* (D'orbiny) and *Valvulineria wilcoxensis*. The agglutinated benthic foraminiferal species encountered within this interval comprises of

Ammobaculites sp.*, Textularia laminata, Spiropectammina wrightii*, *Miliammina* sp and *Haplophragmoides* sp. while *Globorotalia scitula*, *Globorotalia contiuousa, Globorotalia mayeri, Globorotalia obessa, Globigerina bulloides, Globigerina venezuelana, Globigerinoides Globigerinoides trilobus,* and *Globigerinoides sacculifer* were the planktics species characterizing this zone. This biozone is correlated to be older than N6 foraminiferal zone (Blow, 1969; Bolli and Saunders, 1985 and Berggren et al. (1985) and is designated as Early Miocene age.

2. *Cassigerinella chipolensis/ Lenticulina inornata* Zone (4230 – 4120m)

The base and top of this zone are defined by the 17.4/Bur.4Ma Maximum Flooding Surface at 4230m and 16.7Ma Sequence Boundary at 4120m. *Lenticulina inornata* (*D'* Orbigny) which is one of the key inferred zonal marker has it LDO at 4280m; at the condense section. Planktic foraminiferal taxa are few within this zone and also there is almost total absence of arenaceous taxa occurrences within this zone. Calcareous benthic taxa that showed significant occurrences include *Uvigerina sparsicostata* (Cushman & Laiming)*, Brizalina mandoroveensis* (Graham)*, Gaveniella beninensis, Lenticulina grandis (*Cushman)*,* and *Eponides eshira* (De Klasz & Rerat). The zone correlates with the upper section of N6 and lower part N7 of planktonic foraminiferal zone of Blow (1969), Bolli and Saunders (1985) and Berggren et al., (1985). The zone is dated Early Miocene age.

3. *Globigerina continousa/ Brizalina interjuncta / Chilogumbelina victoriana* Zone (4120 – 3930m)

The base of this zone coincided with the 16.7Ma Sequence Boundary at 4120m, while the top is at 15.9/Lang.1Ma Maximum Flooding Surface and is marked by the LDO of *Globigerina continousa* (Blow) at 3930m. The FDO of *Brizalina interjuncta*as zonal marker was observed at interval depth of 4040m and occurred close to the base of this zone. This zone has highly rich calcareous benthic foraminifera and paucity of arenaceous and plankics taxa counterparts. However, calcareous benthic foraminifera taxa characterizing this zone include *Uvigerina sparsicostata (*Cushman & Laiming)*, Brizalina mandoroveensis* (Graham)*, Cibicorbis inflata* (D'Orbigny), *Lenticulina grandis* (Graham), *Valvineria suturalis*, *Uvigerina gallowayi* (Galloway) and *Hopkinsina bononiesis*. This zone is correlated with upper section of N7 to the lower N8 zone of Blow 1969, Bolli and Saunders (1985) and Berggren et al., (1985). The age designation is 'late' Early Miocene to 'early' Middle Miocene age.

4. *Orbulina suturalis/Eponides eshira /Lenticulina grandis* Zone (3930 – 3610m)

This zone is marked by 15.9/Lang.1Ma and 15.0/Ser.2Ma Maximum Flooding Surfaces at 3930m and 3610m respectively indicating the base and top of the intervals. The top of this zone is marked by FDO of the nominate markers species at 3600m; FDO of Orbulina *suturalis (*Bronnmann*),Eponides eshira* (De Klasz & Rerat) and *Lenticulina grandis*. This zone is rich in calcareous benthic species with moderate abundance and diversified arenaeous and planktic taxa when compared to the previous zones. Some of the earlier encountered foraminifera taxa are also witnessed within this zone but some new species such as *Globigerina bulloides* (D'Orbiny)*, Globigerina continousa* (Blow), *Globorotalia mayeri* (Cushman & Ellisor), *Florilus ex.gr. costiferum* (Cushman)*, Heterolepa pseudoungerina* and *Textularia laminata* (De France) have been witnessed. From the work of Blow (1969), Bolli and Saunders, (1985) and Berggren et al., (1985) this zone is designated 'early' Middle Miocene and is correlated to the upper section of N8 and middle part of N9 zones respectively. There is absence of a typical Middle Miocene age index planktic foraminifera encountered in this zone.

5. *Orbulina universa / Uvigerina sparsicostata / Brizalina mandoroveensis* Zone (3610 – 3490m)

The base of this zone is at the topmost section depicting the 15.0/Ser.2Ma Maximum Flooding Surface at 3610m while the top is marked by occurrence of the 13.8Ma Sequence Boundary at 3490m observed within the well understudied. The First downhole occurrence (FDO) of *Brizalina mandoroveensis* (Graham) which is the nominate zonal markers species occurred at 3550m while the LDO of *Orbulina unversa* (D'Orbigny) was observed at 3660m; these index species occurred at the base of the condense section of the maximum flooding surface. This assemblage zone has moderate to high plantkic and benthic foraminifera abundance and diversity. This zone exhibited the same foraminiferal taxa occurrences when compared to the previous zones. This zone correlates with top of N9 to the middle section of N10 zone of Blow (1969), Bolli and Saunders (1985) and Berggren et al., (1985). The age of this zone is designated Middle Miocene.

6. *Globorotalia foshi lobata/ Sigmolina oligoceanica* Zone (3460 – 3490m)

This is the youngest foraminiferal assemblage zone encountered in this study well. The FDO of *Sigmolina oligocaenica* (Cushman) at 3460mstands as the zonal marker and occurred close to the basal interval while the top of this zone is placed at 3460m which is the depth where the first analyzed sample occurred. However this zone is stratigraphically placed at 3490m where the Sequence Boundary of 13.8Ma and the top of this unit is defined as explain above. This zone is characterized by *Globigerinoides trilobus* (Reus)*, Buliminella aff. subfusifomis, Ammonia beccarii* (Linne)*, Florius ex. gr. costitefrum* (Cushman)*, Hanzawaia strattioni (*Graham) *and Textularia panamensis* (De France). This zone is equivalent to upper section of the N10 and younger zone (Blow 1969; Bolli and Saunders, 1985; Hardenbol et al., 2004 and Berggren et al., 1985). The age of the zone is designated as Middle Miocene and younger.

Paleoenvironmental Analysis

Delineation of depositional environments was done based on integration of biofacies, wireline log motifs, lithology and this give rise to eight delineated paleoenvironmetal settings (Fig. 5). Lithological analysis was based on textural properties and its accessories while the gamma ray wireline log motifs helps in the delineation of various depositional environments. Planktic foraminifera species were few in the study area but the increased population of the benthonic (calcareous and arenaceous) taxa greatly attributed to the high influx of continental materials to the basin. However, it has been noted that some benthic foraminifers are paleowater depth indicators and were conspicuously used and integrated with other parameters in delineating the paleobathymetric setting of the studied well (Table 1).

This include:

- Percentage ratio of calcareous to arenaceous benthic foraminifers which increases with water depth (i.e., %FOBC: %FOBA) of Allen, (1965 & 1970) has been used in this study.
- Planktonic percentage (%P) of foraminiferal assemblage provided in Culver (1988) has been utilized.

However, in this study paleoenvironmental and paleodepth classification of Culver (1988) has been utilized (Fig. 6).

Interval: 4370 – 4200m

Paleodepth: Outer Neritic-Upper bathyal (100 – 200m equivalent of Culver, 1988 depth range)

Paleodepositional Environment: Distal Bar

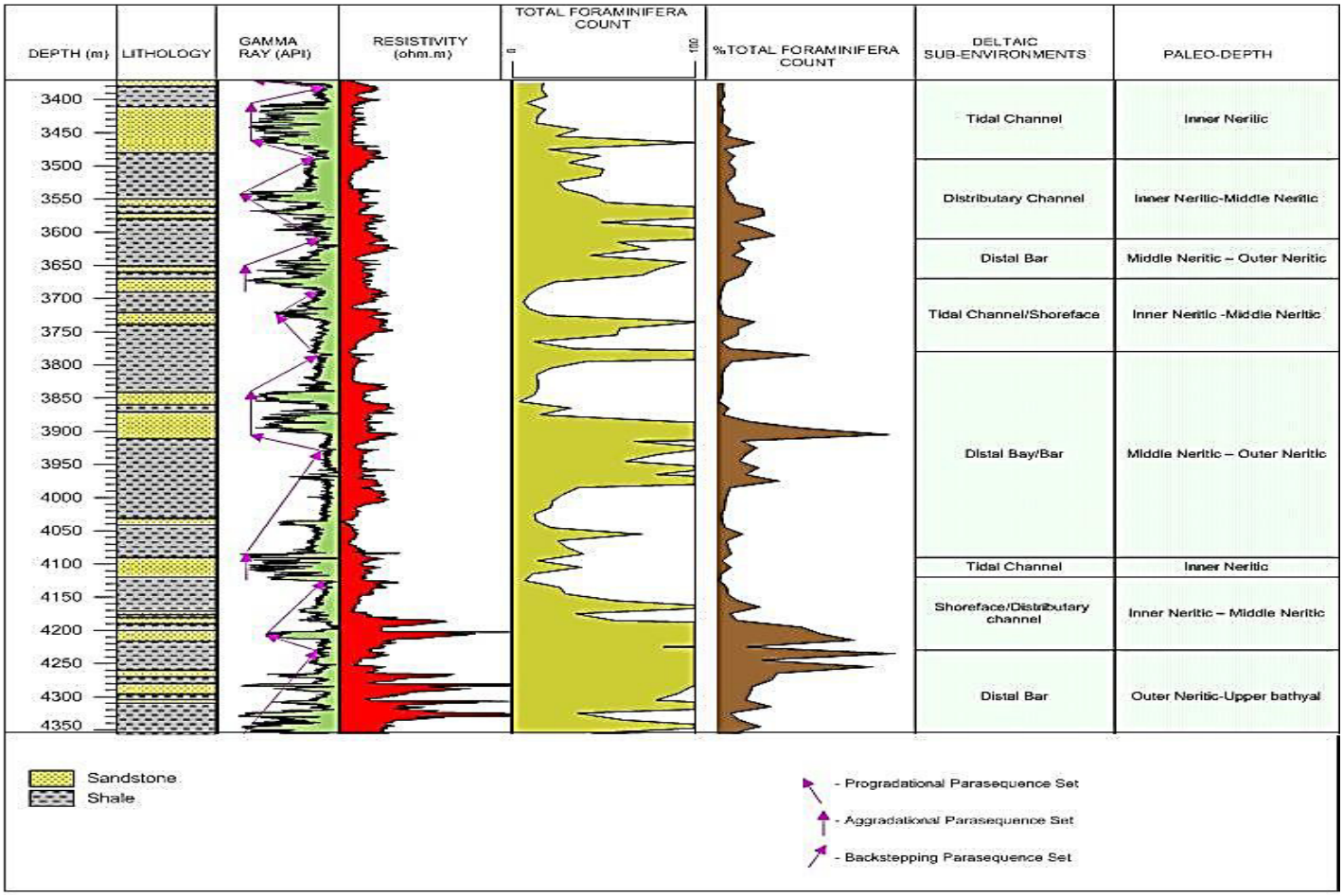

Fig.5. Integration of delineated sub-environment, biofacies, and lithologic log of MR well.

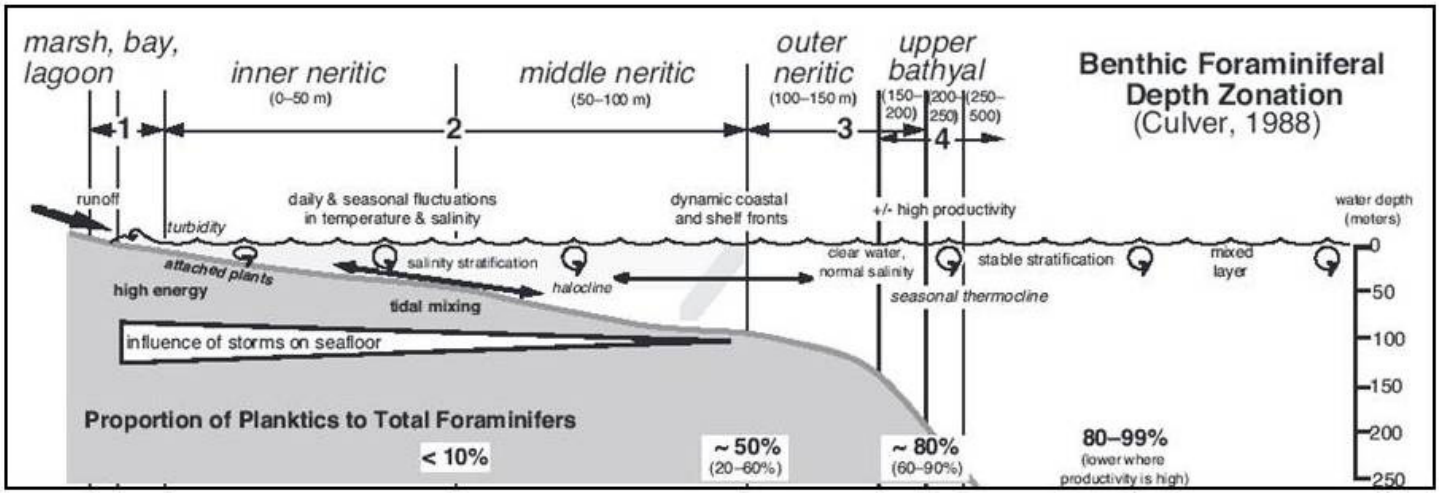

Fig.6. Paleoenvironmental interpretation chart (After Culver, 1988).

Table 1. Quantitative foraminiferal assemblage distribution of "MR"–Well.

Depth (m)	Benthic Foraminiferal Composition.					P	TR	TT	%P	%B	%M	%A	%R	%FOBC	%FOBA
	P	R	TC	A	TBF										
3370-3410	03	63	66	11	77	01	64	78	1.28	98.72	3.85	19.10	82.05	85.71	14.29
3420-3470	04	166	170	18	188	02	168	190	1.05	99.95	2.11	9.47	88.42	90.43	9.57
3480-3520	08	273	281	17	298	24	297	322	7.45	92.55	2.48	5.28	92.24	94.30	5.57
3530-3570	07	251	258	04	262	44	295	306	14.38	85.63	2.29	1.31	96.41	98.47	1.53
3580-3620	26	484	510	05	515	63	547	578	10.90	89.10	4.50	0.86	94.64	99.03	0.97
3630-3670	11	338	349	01	350	32	370	382	8.38	91.62	2.88	0.26	96.86	99.43	0.57
3680-3720	02	52	54	04	58	17	69	75	22.66	77.33	2.67	5.33	92.00	93.10	6.90
3730-3770	04	236	240	11	251	16	252	267	6.00	94.00	1.50	4.12	94.38	95.62	4.38
3780-3820	06	348	354	03	357	03	251	360	0.83	99.17	1.67	0.83	97.50	95.62	4.38
3830-3870	04	50	54	24	78	03	53	81	3.70	96.30	4.94	29.63	65.43	69.23	30.77
3880-3920	05	776	781	07	788	03	779	791	0.38	99.62	0.63	0.89	98.48	99.11	0.89
4930-4970	0	446	446	01	447	05	451	452	1.11	98.89	0	0.22	99.78	99.78	0.22
4980-4020	0	277	277	01	278	02	279	280	0.14	99.29	0	0.36	99.64	99.64	0.36
4030-4070	0	140	140	04	144	03	143	147	2.04	97.96	0	2.72	97.28	97.22	2.78
4080-4120	01	132	133	0	133	02	134	135	1.48	98.52	0.74	0	99.26	100	0
4130-4170	02	224	226	01	227	05	229	232	2.16	97.84	0.86	0.43	98.71	99.56	0.44
4180-4220	0	995	995	0	995	15	1010	1010	1.49	98.51	0	0	100.0	100	0
4230-4270	01	1303	1304	0	1304	56	1359	1360	4.12	95.88	0.07	0	99.93	100	0
4280-4320	0	555	255	16	571	49	604	620	7.90	92.10	0	2.58	97.42	97.20	2.80
4330-4370	02	280	282	01	283	104	384	387	26.87	73.13	0.5	0.26	99.22	99.65	0.35
Total	**86**	**7389**	**7475**	**129**	**7604**	**449**	**7738**	**8053**							

(M = Millolids, R = Rotalina, TC = Total Calcareous, A = Agglutinating, TBF = Total Benthic Foraminifera, P = Planktics, TR = Total Hyaline, TT = Total Taxa, B = Benthic, FOBC = %Benthic Calcareous Foraminifera, FOBA = %Benthic Arenaceous Foraminifera, Tau Value = %Px No. of Benthics),

This interval has the highest abundance and diversity of foraminiferal taxa distribution in this study well. However, planktic taxa were found to be in highest percentage in this section. Ratios of FOBC to FOBA range from 97% – 100%, indicating a deeper paleo-water depths. This assemblage inhibits high abundance and diversified planktic foraminifera such as *Globigerinoides trilobus, Globigerina venezuelana, Globorotalia mayeri, Catapsydrax dissimilis* and *Globigerinoides sacculifer* within the interval. The benthic taxa indicators include: *Valvulinera wilcoxensis, Bulimina* alsatica, *Brizalina mandorovensis, Eponides eshira*, *Uvigerina sparsicostata* and *Lenticulina grandis*. The lithofacies is somewhat monolithic in nature, consisting of over 95% shale sediments. The serrated bell shaped gamma ray log motifs suggests its deposition as a distal bay in a prodeltaic environment (Fig. 5).

Interval: 4030m – 4000m

Paleodepth: Inner Neritic – Middle Neritic (0 – 100m equivalent of Culver, 1988 depth range)

Paleodepositional Environment: Shoreface/ Distributary channel

A significant decrease in abundance and diversity of foraminifera taxa was observed from Middle Neritic at the lower section of this interval to the Inner Neritic in the upper section. However, influx of planktic species such as *Globoratalia mayeri*, *Orbulina* sp.and *Globigerina venezuelana* with persistent occurrences of *Brizalina mandorovensis, Eponides eshira*, *Uvigerina sparsicostata* and *Lenticulina grandis* were also observed within this interval. Foraminiferal value increased considerably as this signified a gradual increase in the paleobathymetry settings ranging from Middle to Inner Neritic paleo water depths. This interval exhibited a shoaling upward sequence pattern with clean to sometimes smoky white, subangular to

sub-rounded sand at the top and with more shale towards the base of this interval. The funnel-shaped log pattern (see Fig.5) indicated a barrier bar sand deposit that exhibited a coarsening upward sequence pattern. A distributary channel at the base of this section was also observed; this showed that the energy exhibited by the sediments during deposition was increasing with geologic time as the coastline advances seawards. These deposits are commonly associated within the shoreline environment and the encountered lithofacies encompasses shoreface sands and offshore silts interbeded with hemipelagic shale.

Interval: 4000 – 3850m

Paleodepth: Inner Neritic (0 – 50m equivalent of Culver, 1988 depth range)

Paleodepositional Environment: Tidal channel

The relative shallowing of paleo-water depths from the preceding interval to predominantly deposition in the Inner Neritic setting with less foraminiferal contents. However, a total absence of agglutinating taxa was recorded within this interval. Calcareous benthic foraminifera such as *Brizalina mandoroveensis*, *Hopkinsina bononiensis* and *Uvigerina sparsicostata* characterized this paleobathymetry setting. The blocky and serrated gamma log motifs (see Fig.5) is an indicative of a tidal channel deposits consisting of predominantly of sand and silts over shale counterparts within this interval.

Interval: 3850 – 3670m

Paleodepth: Middle Neritic – Outer Neritic (50 – 150m equivalent of Culver, 1988 depth range)

Paleodepositional Environment: Distal Bay/Bar

This interval is characterized by the low abundance and diversity of taxa from the bottom to the top of this section with a slight increase in abundance and diversity of taxa towards the middle section (Fig.5) of this interval. There is high occurrence of agglutinating taxa with sporadic distribution of planktic species. The distribution within this interval shows that FOBC ranges from 70% to 99% with FOBA (1% - 31%); which has its highest occurrence of FOBA in the studied well (Table 1). The higher ratios of FOBC: FOBA coupled with the planktic taxa provides a reliable and useful paleoenvironmental guide which indicates a deeper paleo-depth than the previous section. Foraminiferal taxa that were observed in this interval include *Globigerina venezuelana, Globigerina sp, Textularia lateralis* and the persistent occurrences of *Uvigerina sparsicostata*, *Eponideseshira* and *Hopkinina bononensis*. The lithofacies within this unit showed a gradual sand decreases in an upwards direction with increasing shales in a fining upward sequence pattern. There are traces of silts, lignites and shell fragments which was also observed within this unit. The aggradational saw teeth of the gamma ray log motifs (Fig.5) indicates a distal bar deposits within the distal deep marine environment.

Interval: 3670 – 3550m

Paleodepth: Inner Neritic- Middle Neritic (0 – 100m equivalent of Culver, 1988 depth range)

Paleodepositional Environment: Tidal Channel /Shoreface

The environment of deposition within this interval showed a gradual shallowing of sediments from Middle Neritic (at the bottom) to Inner Neritic toward the top of this section. Benthic foraminifera occurring within the Middle Neritic paleo-water depth include calcareous taxa such as influx of *Eponides eshira, Uvigerina gallowayi, Brizalina mandoroveensis* with persistent occurrence of *Uvigerina sparsicostata, Reophax* sp*, Epistominella vitrea, Ammonia beccarii*

and *Hanzawaia strattonii*. There is a gradual decrease in planktic/ benthic ratios with respect to observed abundance and diversity occurrence of foraminifera taxa recorded from bottom to the top of this interval. The paleobathymetry setting has a wide range of depth; occurring from Inner to Middle Neritic. The log signatures characterizing this section showed a cylindrical to symmetrical-hour-glass shaped (Fig.5) which signified a tidal channel to shoreface depositional environments with intermittent shale incursions.

Interval: 3550 – 3370m

Paleodepth: Middle Neritic – Outer Neritic (50 – 150m equivalent of Culver, 1988 depth range)

Paleodepositional Environment: Distal Bar

In this interval, calcareous benthic (FOBC) species is greater than 98% therefore predominates over its agglutinated counterparts (FOBA) as shown in Table 1. This scenario clearly signified a relatively deepening in palaeo-water depth than the overlying section. There is a total upward increase in abundance and diversity of foraminiferal species recorded in this interval as well as high percentage of planktics foraminiferal taxa from bottom to the top of this interval. Some of the foraminifera species which characterize this environment include *Globigerina*sp, *Globigerinoides* sp, *Globorotalia* sp, *Bolivina* sp, *Uvigerina*sp, *Brizalina* sp and *Bolivina* sp. The gamma ray wireline log motifs shows a saw-teeth shapes exhibited by the sand and shale lithofacies indicating deposition in the distal bar environment. Accessories recorded within this interval include shell fragments, pelycepods, ostracods and gastropods. The lithology in this interval include subangular – subrounded, medium to coarse grained, moderately - well sorted sand with shale deposits.

Conclusion

The biostratigraphic, paleoenvironmental and lithological analyses of sediments from 'MR'- well (4370 -3370m) showed that the interval of the well penetrated the paralic sand/shales with silt intercalated sequences belonging to the Agbada Formation. However, from the analysis of the foraminiferal biostratigraphy of 'MR'-well it indicated the establishment of six (6) informal foraminiferal zones. These zones are *Catapsydrax dissimillis/ Buliminella subfusiformis, Cassigerinella chipollensis/Lenticulina inornata, Globigerina continousa/ Brizalina interjuncta/ Chilogumbelina victoriana, Orbulina saturalis/ Eponides eshira/ Lenticulina grandis, Orbulina universa/ Brizalina mandoroveensis* and *Globorotalia foshi lobata/ Sigmolina oligoceanica*.

Based on the associated foraminifera marker species that make up the different biozones, the encountered taxa suggests the Early- Middle Miocene time. Paleoenvironmental deductions were based on the integration of biostratigraphic/biofacies, wireline log (gamma ray) and sedimentologic information. However, six paleobathymetric zones were delineated in this studied well ranging from Shallow-Inner Neritic to Upper bathyal paleowater depths. Paleodepositional environments were delineated based on the shapes of gamma ray log signatures, lithologic attributes and information from the foraminiferal analysis. The various sub-environments delineated include: tidal channel, distributary channel, distal bar, shoreface and point/barrier bars respectively.

Acknowledgement

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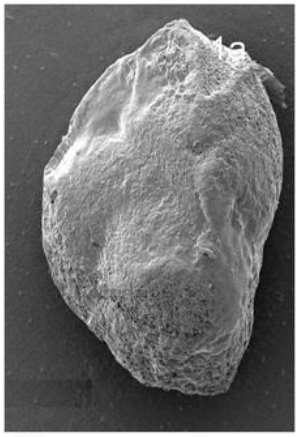
Some photographs of recovered foraminifera

PLATE 1

Uvigerina sparsicostata
(Side view)

Uvigerina sparsicostata
(Side view)

Uvigerina sp
(Side view)

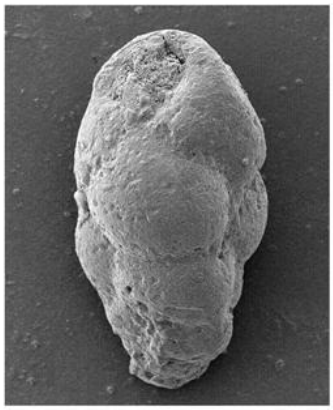


Uvigerina sp.
(Side view)

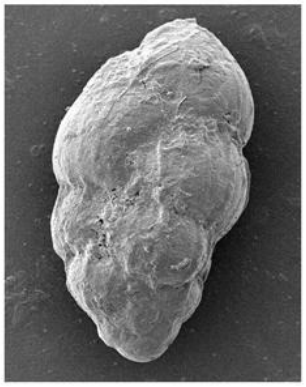
Lenticulina grandis
(Side / Apertural view)

Amphistegina lessonii
(Side view)

Brizalina mandorovensis
(Side view)

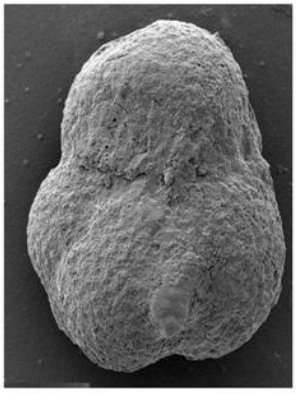


Buliminella aff. subfusiformis
(Side / Apertural view)



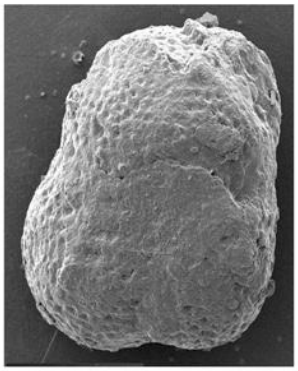
Hopkinsina bononiensis
(Side view)

PLATE 2



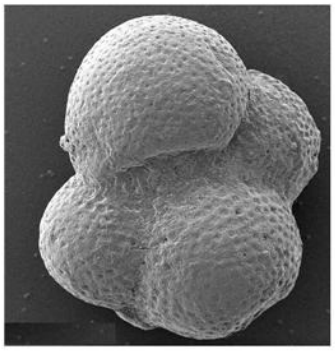
Globigerina bulloides

(Umbilical view)



Globigerina sp.

(Spiral view)

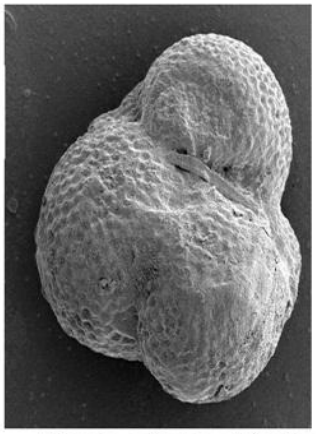


Globigerina venezualana

(Umbilical view)

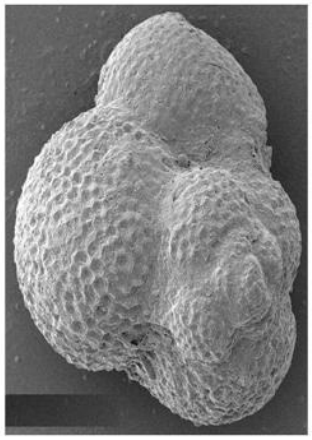
Cassigerinella chipolensis

(Spiral view)



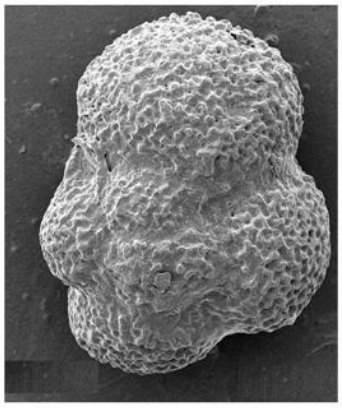
Cassigerinella chipolensis

(Umbilical view)



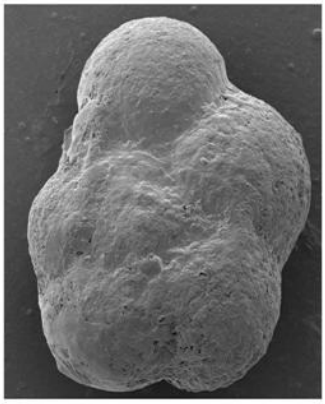
Globigerinoides trilobus

(Spiral view)



Globorotalia continuosa

(Spiral view)



Globorotalia mayeri

(Spiral view)

Globorotalia mayeri

(Spiral view)

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